BIPOLAR PLATE FABRICATION BY ROLL BONDING

FIELD OF THE INVENTION

[0001] The present invention relates to bipolar plates, and more particularly to a method of making a bipolar plate using roll bonding.

BACKGROUND OF THE INVENTION

[0002] Current collector plates or bipolar plates are an integral part of the fuel cell stack. Current collector plates function in a fuel cell stack as fluid distribution elements and function as bipolar plates to separate MEAs from one another. Each plate assembly is typically constructed of thin gauge metal sheets such as stainless steel coated with a conductive coating. Generally, two adjacent metal sheets are joined together forming a conductive heat exchanger. The joined plate assembly has internal flow channels along its length for coolant flow. Channels on either side of the bipolar plate serve as distribution pathways for fuel and oxidant gas to adjacent current collectors. A hermetic seal is required around the perimeter of the joined plates to prevent mixing of the coolant, fuel, oxidant gas and reactant products. High conductivity must be maintained between the two metal sheets that form the bipolar plate to achieve efficient fuel cell operation.

[0003] A conventional method of constructing a bipolar plate has been to first stamp the flow channels into the sheet material and subsequently join the sheets together. Stamping however is unfavorable because it subjects the sheets to high strains and distortion. In addition, joining stamped structures may be complicated. First, after stamping, there is minimal sheet to sheet contact between flow channels, thus, alignment and weld containment are difficult.

Secondly, access for joining between the flow channels is obstructed by the flow channel structure.

[0004] A variety of joining techniques have been considered to overcome the drawbacks associated with conventional stamping followed by joining. These include brazing, adhesive bonding and fusion welding. These too, however, present unfavorable drawbacks. Brazing of austenitic stainless steel has been successful, but is costly. The cost is partially attributed to the acid cleaning and batch coating necessary after the brazing operation. Both adhesive bonding and fusion welding allow the stainless sheet to be acid cleaned and coated with a continuous coil operation prior to joining which is less costly. Adhesive bonding, however, suffers from durability issues regarding strength and conductivity. Fusion welding of austenitic stainless steel produces a number of potential concerns including distortion, weld cracking, sensitization, stress corrosion cracking, degraded corrosion resistance, damage to the organic coating, sheet alignment, access between flow channels and small contact areas between flow channels for weld containment.

SUMMARY OF THE INVENTION

[0005] A method for making a current collector plate includes providing a first sheet of material having a first bonding face and a first outer face. A second sheet of material is provided having a second bonding face and a second outer face. A plurality of patterned areas are created on at least one of the first bonding face and the second bonding face. The first and second sheets are bonded together. Pressurized fluid is injected between the first and second sheet

thereby causing at least one of the first and second sheets to project outwardly at the plurality of patterned unbonded areas.

[0006] In other features, forming a plurality of patterned areas includes placing an anti-bonding material on at least one of the first bonding face and the second bonding face and defining bonding areas at the remaining areas of the first bonding face and the second bonding face. Bonding the first and second sheets together includes contacting the first bonding face with the second bonding face. A force is imposed onto at least one of the first and second outer faces thereby joining the first and second sheets at the bonding area.

[0007] According to other features, injecting fluid includes placing the first and second bonded sheets into a die having spaced apart first and second boundaries. Fluid is injected between the first and second sheet whereby the extension portions contact one of the first and second boundaries so as to form a flat surface thereat. A flow channel is formed between the first and second sheet.

[0008] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0010] FIG. 1 is a schematic isometric exploded illustration of a PEM fuel stack;

[0011] FIG. 2 is a sectional view of a cooled bipolar plate of FIG. 1;

[0012] FIG. 3 is a perspective view of a sheet of conductive material having an anti-bonding material disposed thereon;

[0013] FIG. 4 is a cutaway view of a first and second sheet of conductive material bonded together after a roll bonding operation;

[0014] FIG. 5 is the cutaway view of FIG. 4 shown after a pressure forming operation;

[0015] FIG. 6 is a depiction of an exemplary assembly process according to the present invention; and

[0016] FIG. 7 is a flow diagram illustrating steps for roll bonding and pressure forming a bipolar plate according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] The following description of the preferred embodiment is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements.

[0018] FIG. 1 schematically depicts a partial PEM fuel cell stack having a pair of membrane-electrode-assemblies (MEAs) 8 and 10 separated from each other by a non-porous, electrically-conductive bipolar plate 12. Each of the MEAs 8, 10 have a cathode face 8c, 10c and an anode face 8a, 10a. The MEAs 8 and 10, and bipolar plate 12, are stacked together between non-porous, electrically-conductive, liquid-cooled bipolar plates 14 and 16. The bipolar plates 12, 14 and 16 each include flow fields 18, 20 and 22 having a plurality of flow channels formed in the faces of the plates for distributing fuel and oxidant gases (e.g., H_2

and O_2) to the reactive faces of the MEAs 8 and 10. Nonconductive gaskets or seals 26, 28, 30 and 32 provide a seal and electrical insulation between the several plates of the fuel cell stack.

[0019] Porous, gas permeable, electrically conductive sheets 34, 36, 38 and 40 press up against the electrode faces of the MEAs 8 and 10 and serve as primary current collectors for the electrodes. Primary current collectors 34, 36, 38 and 40 also provide mechanical supports for the MEAs 8 and 10, especially at locations where the MEAs are otherwise unsupported in the flow field. Suitable primary current collectors include carbon/graphite paper/cloth, fine mesh noble metal screens, open cell noble metal foams, and the like which conduct current from the electrodes while allowing gas to pass therethrough.

[0020] Bipolar plates 14 and 16 press up against the primary current collector 34 on the cathode face 8c of MEA 8 and primary current collector 40 on the anode face 10a of MEA 10, while the bipolar plate 12 presses up against the primary current collector 36 on the anode face 8a of MEA 8 and against the primary current collector 38 on the cathode face 10c of MEA 10. An oxidant gas such as oxygen or air is supplied to the cathode side of the fuel cell stack from a storage tank 46 via appropriate supply plumbing 42. Similarly, a fuel such as hydrogen is supplied to the anode side of the fuel cell from a storage tank 48 via appropriate supply plumbing 44. In a preferred embodiment, the oxygen tank 46 may be eliminated, and air delivered to the cathode side from the ambient. Likewise, the hydrogen tank 48 may be eliminated and hydrogen supplied to the anode side from a reformer which catalytically generates hydrogen from methanol or a liquid hydrocarbon (e.g., gasoline). Exhaust plumbing (not shown) for both the H_2 and O_2 / air sides of the MEAs is also provided for removing H_2

depleted anode gas from the anode flow field and O_2 depleted cathode gas from the cathode flow field. Coolant plumbing 50 and 52 is provided for supplying and exhausting liquid coolant to the bipolar plate 12, as needed. It is appreciated that coolant may additionally or alternatively be provided to the bipolar plates 14 and 16.

[0021] Turning now to FIG. 2, the bipolar plate 12 is shown in greater detail. The bipolar plate 12 generally includes a first and second plate 60, 62 joined together at a predetermined bonding area 68 as will be described in greater detail. The first and second plate 60, 62 are preferably comprised of a conductive material such as aluminum alloy or stainless steel for example. The flow channels 18 of the bipolar plate 12 are further defined by an anode flow field 70 disposed on an outer surface of the first plate 60, a cathode flow field 72 disposed on an outer surface of the second plate 62 and a coolant flow field 76 disposed between the first and second plates 60, 62. In operation, the anode flow field 70 of the first plate 60 distributes the fuel to the anode face 8a of the MEA 8. Similarly, the cathode flow field 72 of the second plate 62 distributes the oxidant gas to the cathode face 10c of the MEA 10. Coolant is communicated through the coolant flow field 76 through the coolant plumbing 50 and 52.

[0022] With reference now to FIGS. 3 – 6, a method of making the bipolar plate 12 according to the present invention will be described in greater detail. In a preferred method, the first and second plate 60, 62 are joined prior to forming the channels 18 of the flow fields 70, 72 and 76. First, a strip of conductive material 78 is rolled from stock or otherwise acquired. The strip should be in the annealed or softened condition. Next, an anti-bonding material 80 (FIG. 3) is placed onto a bonding face 82 of the strip of material 78. The anti-

bonding material 80 may comprise colloidal-graphite for example. It is appreciated however that other anti-bonding materials may be employed.

[0023] The anti-bonding material 80 is placed in a pattern representing a desired flow field (FIG. 3) hereinafter referred to as the expansion area 84. Next, the strip of material 78 having the anti-bonding material 80 along with a complementary strip of conductive material 88 is passed through a rolling mill that bonds the two strips together in the areas that did not contain the anti-bonding pattern hereinafter referred to as the bonding area 94. The rolling mill imposes a compression force onto the two sheets 78, 88 causing a thickness reduction and a metallurgical bond at the bonding area 94. The two bonded sheets 78, 88 comprise a two-piece bonded plate and further represent the first and second plate 60, 62 of the bipolar plate 12.

[0024] With specific reference to FIGS. 4 and 5, pressurized fluid is introduced between the two bonded sheets 78, 88 to form the respective flow channels 18 (FIG. 2). As shown, the bonding area 94 of the two sheets 78, 88 remains bonded and the expansion area 84 is expanded outwardly. Preferably, an outer boundary 96 is placed a predetermined lateral distance from respective outer surfaces 98, 100 of the first and second plate 60, 62. The outer boundary 96 is configured to define the flow channel depth and additionally, encourages the formation of a flat surface top on the flow channels desirable for electrical contact in the fuel cell stack, improving dimensional tolerance and decreasing contact stresses between plates.

[0025] Turning now to FIGS. 6 and 7 steps for fabricating a bipolar plate according to the present invention are shown generally at 200. Fabrication begins with step 202. In step 204 the sheet of material 78 is rolled from stock. In

step 208, the anti-bonding material 80 is placed in a desired pattern onto the sheet of material 78 through a rolling applicator 102. In step 212 the sheet of material 78 along with the complementary sheet of material 88 is introduced into a rolling mill 104. The rolling mill 104 provides a bond at the bonding area 94 thereby joining the two sheets 78 and 88 together. In step 216, the joined sheets 78, 88 are annealed with an annealing device 106. In step 220 the sheets 78, 88 are cleaned through a continuous clean and rinse bath 108.

[0026] In step 224, a coating to encourage conductivity is applied through a roll coating apparatus 110 on the outer surfaces 98, 100 of the sheets 78, 88. In step 228 the sheets 78, 88 are cut from the roll by a blanking press 114 defining the first and second plates 60, 62. The plates 60, 62 are then placed into a fixture 120 such as a die having the outer boundaries 96 and fluid is introduced between the plates 60, 62 in step 230. In step 232 the newly formed bipolar plates 12 are trimmed and holes including header apertures are placed in desired locations by a trimming tool 130. Fabrication ends in step 234.

[0027] It is appreciated that some of the steps 200 outlined in the preceding discussion may be modified or placed in an alternative sequence. For example the application of the conductive coating in step 224 may alternatively be applied before the roll bonding step 212. In addition, header apertures may alternatively be formed during the fluid expansion step 230. Accordingly, die extensions may be incorporated into the fixture 120 that encourage headers to form in the header portion of the bipolar plate 12 upon fluid expansion.

[0028] Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has been described in

connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, the specification and the following claims.